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Volume 8 Additional Information

Appendix 3: Herring Additional Information Note

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OW
OCEAN WINDS

Volume 8 Appendix 3: Herring Additional Information Note

Code	UKCAL-CWF-CON-EIA-RPT-00008-1003
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Acronyms and Abbreviations

dB	Decibel
EIAR	Environmental Impact Assessment Report
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larvae Survey
MD-LOT	Marine Directorate – Licensing Operations Team
OECC	Offshore Export Cable Corridor
OWF	Offshore Wind Farm
PEMP	Project Environmental Monitoring Plan
PMF	Priority Marine Feature
TTS	Temporary Threshold Shift
SEL_{cum}	Cumulative Sound Exposure Level
UWN	Underwater Noise

1 Introduction

1.1 Project Overview

1.1.1.1 In November 2024, Caledonia Offshore Wind Farm Limited (hereafter referred to as the 'Applicant') submitted consent applications to the Marine Directorate – Licensing Operations Team (MD-LOT) to develop the Caledonia Offshore Wind Farm (OWF) (hereafter referred to as the 'Proposed Development (Offshore)') within the Outer Moray Firth, off the north-east coast of Scotland.

1.1.1.2 The Proposed Development (Offshore) includes the Caledonia Array Area (hereafter referred to as 'Caledonia OWF') and the Caledonia Offshore Export Cable Corridor (OECC). To support with the deliverability of these phases, the Applicant has submitted two offshore consent applications (Section 36 and associated Marine Licences) for the Proposed Development (Offshore), referred to as Caledonia North and Caledonia South.

1.1.1.3 Further details on the Proposed Development (Offshore) Design Envelope and amendments to the design since submission of the Environmental Impact Assessment Report (EIAR) are presented in Section 4 of Volume 8: Caledonia Offshore Wind Farm EIAR and HRA Addendum.

1.2 Purpose of the Document

1.2.1.1 The potential impacts of the Proposed Development (Offshore) on Atlantic herring (*Clupea harengus*) including the Proposed Development (Offshore) alone and cumulative with other plans and projects, are detailed within Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology of the EIAR, which was submitted to MD-LOT as part of the offshore consent application in November 2024. Following the submission of the consent applications, a formal consultation period was held, during which statutory consultees and the public were invited to provide feedback.

1.2.1.2 Herring have been identified as one of the key receptors likely to be affected by impulsive noise emitted during the piling of foundations for the Caledonia OWF based upon the species' sensitivity to underwater noise (UWN) and the presence of active herring spawning grounds within the fish and shellfish ecology Study Area. During the consultation, concerns were raised by NatureScot (letter dated 27 March 2025), relating to the potential for adverse UWN effects on Atlantic herring, particularly in the context of potential cumulative impacts from other marine industries and offshore wind farm developments in the area. Subsequently, this appendix has been prepared to address these concerns, drawing on information presented within the EIAR to provide further justification for the Proposed Development (Offshore) alone and cumulative impact assessments for Atlantic herring in relation to UWN emitted during piling activities.

1.2.1.3 The relevant documents submitted as part of the EIAR that should be read in conjunction with this appendix are:

- Volume 1, Chapter 3: Proposed Development Description(Offshore);
- Volume 2, Chapter 5: Fish and Shellfish Ecology;
- Volume 3, Chapter 5: Fish and Shellfish Ecology;
- Volume 4, Chapter 5: Fish and Shellfish Ecology;
- Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report; and
- Volume 7, Appendix 6: Underwater Noise Assessment.

2 Herring Spawning in the Study Area and Wider North Sea

2.1.1.1 The importance of the fish and shellfish ecology Study Area for herring has been described within the Fish and Shellfish Technical Baseline Report of the EIAR (Volume 7B, Appendix 5-1), which was submitted as part of the original application documentation. Within the wider North Sea, multiple herring spawning components can be distinguished, based on the specific areas used for spawning and the timing of the spawning period (International Council for the Exploration of the Sea (ICES), 2005[1]; Figure 2-1). The spawning components of relevance to the Proposed Development (Offshore) are the Orkney/Shetland and Buchan components, which together with the Banks and Downs (Southern Bight) components comprise the four autumn-spawning herring groups present in the North Sea (Bierman *et al.*, 2010[2]).

2.1.1.2 While the four spawning components identified above are all referred to as autumn spawners, there is some variation in the spawning period across them; Buchan and Orkney/Shetland herring spawn during August and September, Banks herring spawn from August to October, and Downs herring spawn during November to January (ICES, 2005[1]). It is notable, however, that all four components mix outside of the spawning seasons and are fished as one stock (Dickey-Collas *et al.*, 2010[3]).

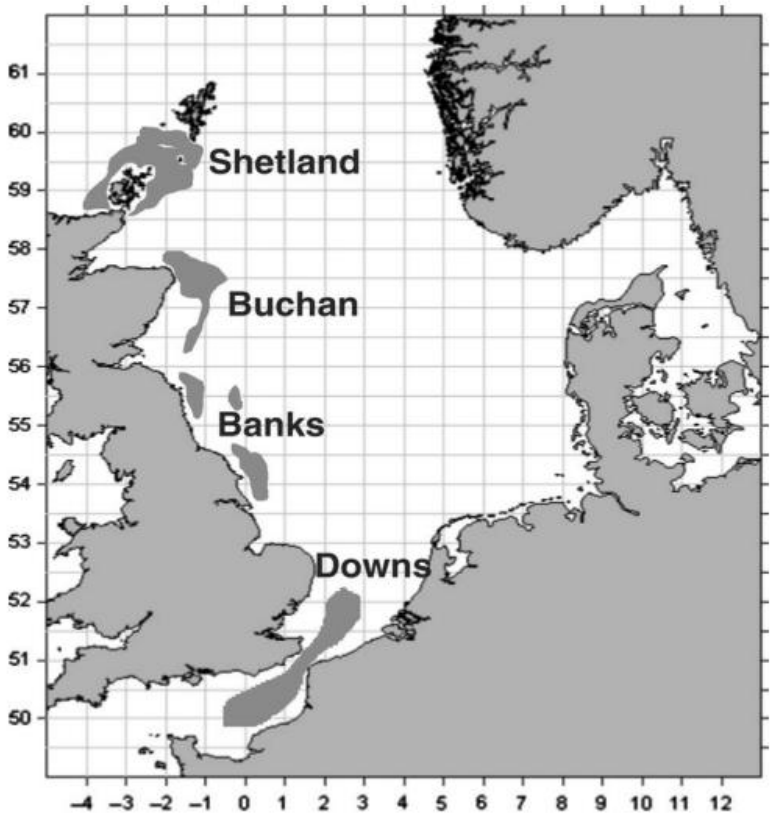


Figure 2-1: Autumn Herring Spawning Components in the North Sea (Bierman *et al.*, 2010[2]).

3 Impact Assessment

3.1 Assessment Methodology

3.1.1.1 Potential effects of underwater noise on Atlantic herring have been assessed in Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology of the EIAR using magnitude and sensitivity criteria to determine the significance of the effect, as detailed in the Assessment Methodology sections of these chapters.

3.2 Sensitivity of Herring to Piling Noise

3.2.1.1 As set out in Section 5.5 (EIA Approach and Methodology) of Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology, the determination of sensitivity of herring to piling noise has been based on three criteria:

- The species' vulnerability to impulsive sounds produced during piling;
- The potential for herring to recover from any noise effects; and
- The value/importance of herring within the study area and wider region.

3.2.1.2 Herring have a swim bladder and two pairs of air bubbles in the inner ear that aid sound detection (Mann *et al.*, 2005[4]; Popper *et al.*, 2022[5]). The presence of these air-filled chambers makes herring more prone to suffer from pressure-related tissue damage or death following exposure to impulsive sounds produced during pile driving activities (Popper *et al.*, 2014[6]). Given their good hearing ability, herring are also at higher risk of experiencing behavioural disturbance and temporary changes in hearing sensitivity (i.e., Temporary Threshold Shift (TTS)). Therefore, as set out in Section 5.7.1 of Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology, the vulnerability of herring to impulsive piling noise has been classed as 'high'. The vulnerability determination has considered that both the survival and reproduction rates of herring could be affected during piling, through a combination of lethal and recoverable injuries, TTS and behavioural changes in spawning herring.

3.2.1.3 Regarding behavioural changes, existing data suggest that while herring can be highly reactive to UWN, the type and strength of behavioural responses may vary depending on the activity individuals were involved in during noise exposure. For example, studies examining the effects of seismic airguns and naval sonars on herring showed a strong response during overwintering but limited change in swimming behaviour during feeding migrations (Doksaeter *et al.*, 2009[7]; Pena *et al.*, 2013[8]). Similarly, strong vessel avoidance has been observed in overwintering herring (Vabø *et al.*, 2002[9]), while no avoidance in response to vessels was observed in spawning herring (Skaret *et al.*, 2005[10]). Whilst there are currently no studies on TTS and behavioural changes in spawning herring during pile

driving specifically, similar damping of behavioural reactions may occur as for other stimuli, reducing the likelihood of effects on spawning success.

3.2.1.4 The ability of herring to recover from piling noise effects has been assessed as 'medium'. It is noted by the Applicant that the determination of recoverability was made at a population level rather than at the individual level (i.e., the assessment has considered the general ability of the Buchan and Orkney/Shetland spawning stocks as a whole to recover). Piling itself will not change the characteristics of potential suitable spawning substrates. Moreover, as can be seen in Figures 5-15 and 5-19 of Chapter 5: Fish and Shellfish Ecology, any potential lethal effects would only affect a small proportion of the Buchan and Orkney/Shetland spawning components in areas outside peak spawning activity. Sub-lethal effects including TTS are likely to affect a larger proportion of the spawning stocks; however, as detailed in Chapter 5: Fish and Shellfish Ecology of the respective EIAR Volumes, these effects are anticipated to be temporary and reversible. Existing studies showed that fish affected by TTS recovered to normal hearing levels within 18-24 hours to several days after noise exposure, depending on the intensity and duration of exposure (Popper *et al.*, 2014[6]; Popper and Hawkins, 2019[11]). Any potential behavioural responses are also expected to be temporary, with individuals anticipated to resume normal behaviours shortly after noise disturbance has ceased.

3.2.1.5 In addition, given the intermittent nature of piling, herring may be able to spawn between individual piling events, even when previously disturbed. It is therefore the Applicant's view that herring have the potential to recover from piling noise effects that may occur during the construction of the Proposed Development (Offshore). It is acknowledged that recovery may take several years given the potential for localised lethal and sub-lethal effects and the potential for a temporary decrease in the reproductive output to a small part of the Buchan and Orkney/Shetland spawning components. Therefore, the recoverability of herring to the impact was deemed to be 'medium'.

3.2.1.6 The sensitivity assessment further considered herring to be of national importance owing to the species' listed status as Priority Marine Feature (PMFs), its commercially importance for UK fisheries and its ecological importance as key prey item for many vulnerable species including Annex II species.

3.2.1.7 Based upon the criteria set out in Table 5-10 of Volumes 2, 3 and 4 Chapter 5: Fish and Shellfish Ecology, the sensitivity of spawning herring to noise impacts was concluded to be **Medium**, acknowledging the national importance of herring, their high vulnerability to piling noise and their medium recoverability.

3.3 Magnitude of Impact for the Proposed Development (Offshore) Alone

3.3.1 Overview

3.3.1.1 Further technical refinement of anchor and piling assumptions following submission of the consent applications in November 2024 has secured a total reduction in anchors from 18 to six per tension-leg platform foundation within the Design Envelope. This has also resulted in a reduction of piling days by 34% for the Proposed Development (Offshore) to 339 piling days, which includes a reduction of piling days for Caledonia South to 275 piling days.

3.3.1.2 To inform the magnitude assessment associated with UWN from piling of foundations, predictive UWN modelling has been undertaken for various foundation types, full details of which have been presented in Volume 7, Appendix 6: Underwater Noise Assessment of the EIAR. In addition, with site-specific and regional sediment data were analysed to map the distribution of substrates suitable for herring spawning (Figure 3-1), following the methodology by Kyle-Henney *et al.* (2024[12]), as described in paragraph 2.4.2.8 *et seq.* within Volume 7B, Appendix 5-1: Fish and Shellfish Technical Baseline Report of the EIAR. Moreover, International Herring Larvae Survey (IHLS) data from 2011 to 2023 were analysed and presented as a 'heat map' (Figure 3-2) to determine the spatial extent of current herring spawning activity in relation to Caledonia North, Caledonia South and the wider northern North Sea region.

3.3.1.3 Analysis of the sediment data showed that the Proposed Development (Offshore) is located within a much wider area of 'Preferred' and 'Marginal' herring spawning substrata, with the Caledonia OWF containing sediments that are mostly 'Unsuitable' for herring spawning (Figure 3-1), indicating a low likelihood of spawning. Localised areas of 'Preferred' and 'Marginal' spawning sediments, corresponding to coarse substrates, are located to the east and west of the Caledonia OWF and in the nearshore along the southern coast of the Moray Firth, including the Caledonia OECC. The IHLS data indicate that the main spawning activity of the Buchan spawning stock is concentrated to the south-east of the Caledonia OWF at the Buchan spawning grounds off Peterhead, while spawning activity of the Orkney/Shetland spawning component peaks to the east and north-east of the Orkney Isles (Figure 3-2).

3.3.1.4 Herring are demersal spawners that exhibit spawning site fidelity and as such they rely upon specific benthic locations for spawning (e.g., Frost and Diele, 2022[13]). Therefore, for the purpose of modelling the potential impact ranges of underwater noise, herring have been considered a stationary receptor, increasing their theoretical exposure to UWN from the construction phase of the development. As detailed in Volume 7, Appendix

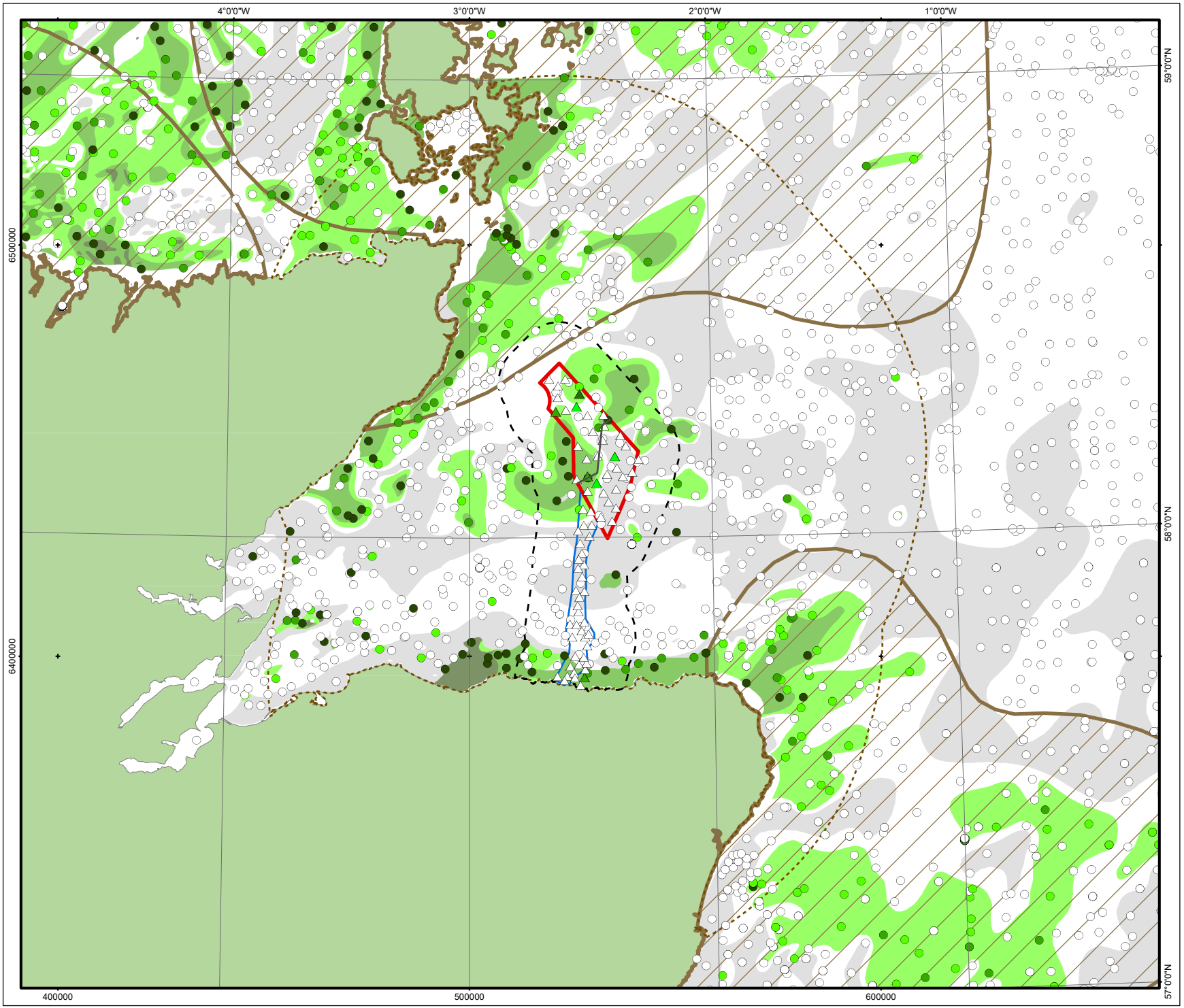
6: Underwater Noise Assessment of the EIAR, the largest impact ranges during the piling at a single location were predicted for the sequential installation of bottom-fixed multi-leg jacket foundations at the easternmost corner of the Caledonia OWF (modelling location 7), due to the deep water at and surrounding this site. The largest spatial extent of impacts (in terms of the area likely to be exposed to sounds above relevant effect thresholds) was predicted for the concurrent piling of bottom-fixed pin-piles at the north-west and south-east corner of the Caledonia OWF, as shown in Figure of 5-15 of Volumes 2, 3, and 4, Chapter 5: Fish and Shellfish Ecology.

3.3.2 Mortality and Potential Mortal Injury and Recoverable Injury

3.3.2.1 Overlap of the noise modelling contours with the IHLS data indicate the potential for mortal and potential mortal injuries and recoverable injuries in herring if piling where to occur during the spawning season (Figure 3-3 and Figure 3-4). However, as shown by annual IHLS data (Figure 3-5 to Figure 3-9), the main spawning of the Buchan and Orkney/Shetland herring spawning stocks regularly occurs south and north of the Proposed Development (Offshore), respectively. It is recognised that there is annual variability in the areas used for spawning, with the area surrounding the Caledonia OWF being relatively more important for spawning in some years. However, even in years of higher spawning activity, the relative importance of the areas surrounding Caledonia OWF for herring spawning remains localised when compared to the spatial extent of areas over which peak spawning consistently takes place. This is further supported by the site-specific and regional PSA datasets which show the availability of suitable herring spawning substrates across the Proposed Development (Offshore) and the wider northern North Sea.

3.3.2.2 It is therefore the Applicant's view that the proportion of the Buchan and Orkney/Shetland spawning components that would be impacted by piling noise is minor when compared to the areas of peak herring spawning across the Buchan and Orkney/Shetland spawning grounds and that this level of impact will not lead to material changes to both spawning stocks. On this basis, the Applicant considers the magnitude assessment of **Low** (adverse) for mortal and recoverable injuries, as presented in Volumes 2, 3 and 4 of Chapter 5: Fish and Shellfish Ecology, to be appropriate.

3.3.2.3 It is noted that Figures 5-15 and 5-19 in Chapter 5: Fish and Shellfish Ecology of EIAR Volumes 2, 3 and 4 contained an error in the mapped cumulative Sound Exposure Level (SEL_{cum}) contours for mortality and potential mortal injury and recoverable injury for herring, showing the 219 decibel (dB) and 216 dB contours instead of the 207 dB and 203 dB contours, respectively. Revised figures showing the correct contours have been produced and included in this appendix. Whilst the areas of each of these contours does increase slightly, this does not impact the magnitude as described in the original assessment and detailed within this appendix.



Caledonia OWF
Offshore Export Cable Corridor
Caledonia North Site and Caledonia South Site Division Line
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Herring Spawning Grounds (Coull et al., 1998)

Herring Habitat Suitability (Reach *et al.*, 2013) (Gardline Limited and Titan Environmental Surveys, 2023)

- Prime, Preferred
- Sub-Prime, Preferred
- Suitable, Marginal
- Unsuitable

Herring Habitat Suitability (Reach *et al.*, 2013) (BGS, 2015)

- Prime, Preferred
- Sub-Prime, Preferred
- Suitable, Marginal
- Unsuitable

Seabed Substrate (EMODnet) Herring Habitat Suitability (Reach *et al.*, 2013)

- Preferred
- Sub-Prime, Preferred
- Marginal
- Unsuitable

0 10 20 30 40 50 km

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Figure 3-1: Herring Spawning Substrates Relative to the Study Area

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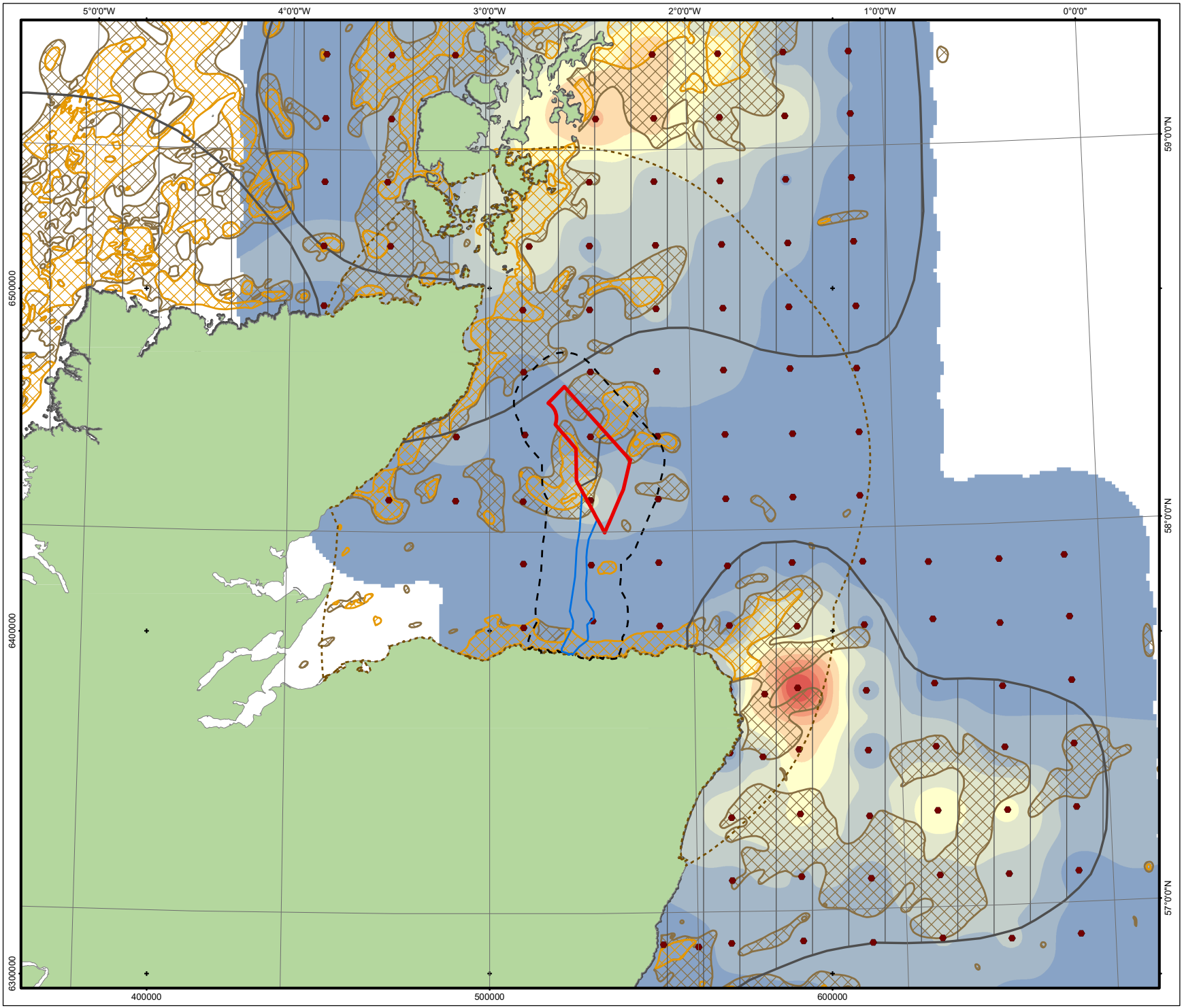

Caledonia OWF
Offshore Export Cable Corridor
Caledonia North Site and Caledonia South Site Division Line
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Herring Spawning Grounds (Coull et al., 1998)

EMODnet Sediment Class Herring Habitat Suitability

Marginal Sediment
Preferred Sediment

International Herring Larvae Survey

Sample Location (2011 - 2024)

IHLS Season 2011-12 to Season 2023-24 - Larval abundance per m²

0.1 - 1,500
1,500.1 - 3,500
3,500.1 - 5,500
5,500.1 - 9,500
9,500.1 - 14,500
14,500.1 - 20,000
20,000.1 - 26,000
26,000.1 - 35,000
35,000.1 - 45,000
45,000.1 - 59,000

0 10 20 30 40 50 km

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Figure 3-2: Indicative Herring Spawning Data Relative to the Study Area (IHLS, 2011-2024)

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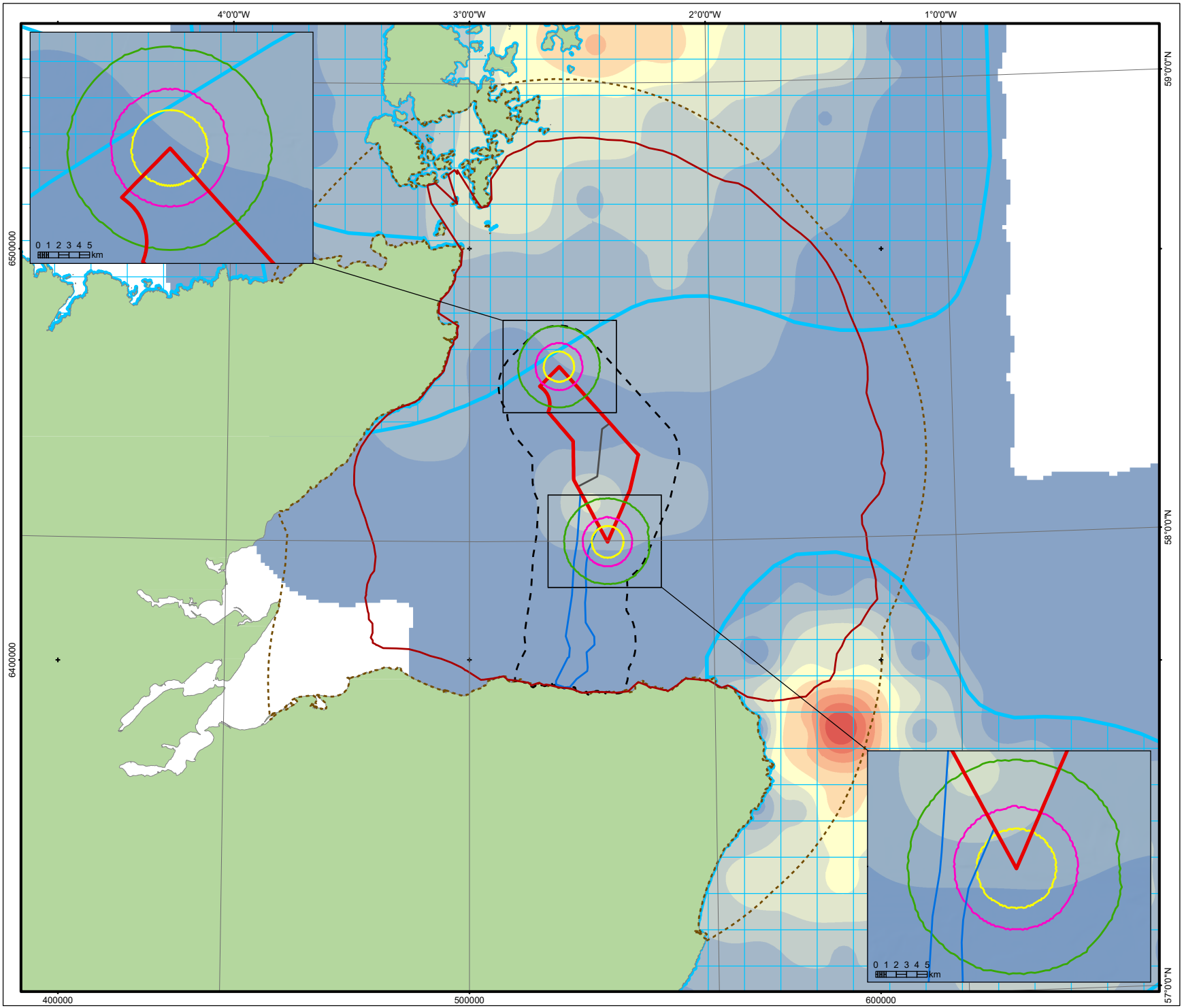

Caledonia OWF

Offshore Export Cable Corridor

Caledonia North Site and Caledonia South Site Division Line

70km Primary Underwater Noise Zone of Influence

10km Secondary Zone of Influence

Pin Piles x4 Contours (Stationary)

186dB (SELcum)

203dB (SELcum)

207dB (SELcum)

210dB (SELcum)

Herring Spawning Grounds (Coull *et al.*, 1998) - Intensity

Undetermined

IHLS Season 2011-12 to Season 2023-24 - Larval abundance per m^2

0.1 - 1,500

1,500.1 - 3,500

3,500.1 - 5,500

5,500.1 - 9,500

9,500.1 - 14,500

14,500.1 - 20,000

20,000.1 - 26,000

26,000.1 - 35,000

35,000.1 - 45,000

45,000.1 - 59,000

0 10 20 30 40 50 km

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Figure 3-3: Predicted Worst Case Impact Ranges for Spawning Herring from the Simultaneous Sequential Piling of 4 Pin-Piles at the North and South of Caledonia OWF

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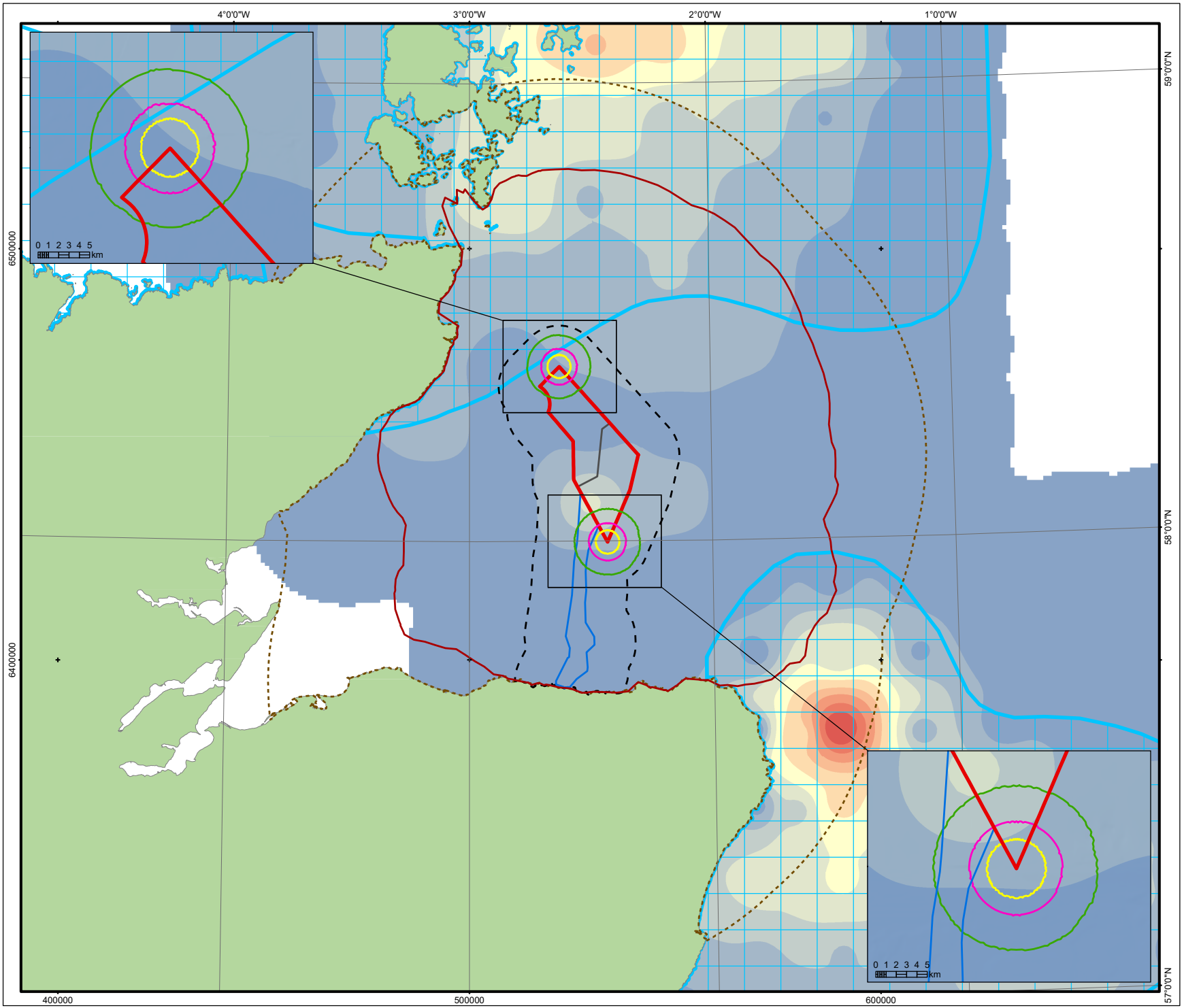

Caledonia OWF

Offshore Export Cable Corridor

Caledonia North Site and Caledonia South Site Division Line

70km Primary Underwater Noise Zone of Influence

10km Secondary Zone of Influence

Monopiles x2 Contours (Stationary)

186dB (SELcum)

203dB (SELcum)

207dB (SELcum)

210dB (SELcum)

Herring Spawning Grounds (Coull *et al.*, 1998) - Intensity

Undetermined

IHLS Season 2011-12 to Season 2023-24 - Larval abundance per m^2

0.1 - 1,500

1,500.1 - 3,500

3,500.1 - 5,500

5,500.1 - 9,500

9,500.1 - 14,500

14,500.1 - 20,000

20,000.1 - 26,000

26,000.1 - 35,000

35,000.1 - 45,000

45,000.1 - 59,000

0 10 20 30 40 50 km

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DRAWING TITLE
Figure 3-4: Predicted Worst Case Impact Ranges for Spawning Herring from the Simultaneous Sequential Piling of 2 Monopiles at the North and South of Caledonia OWF

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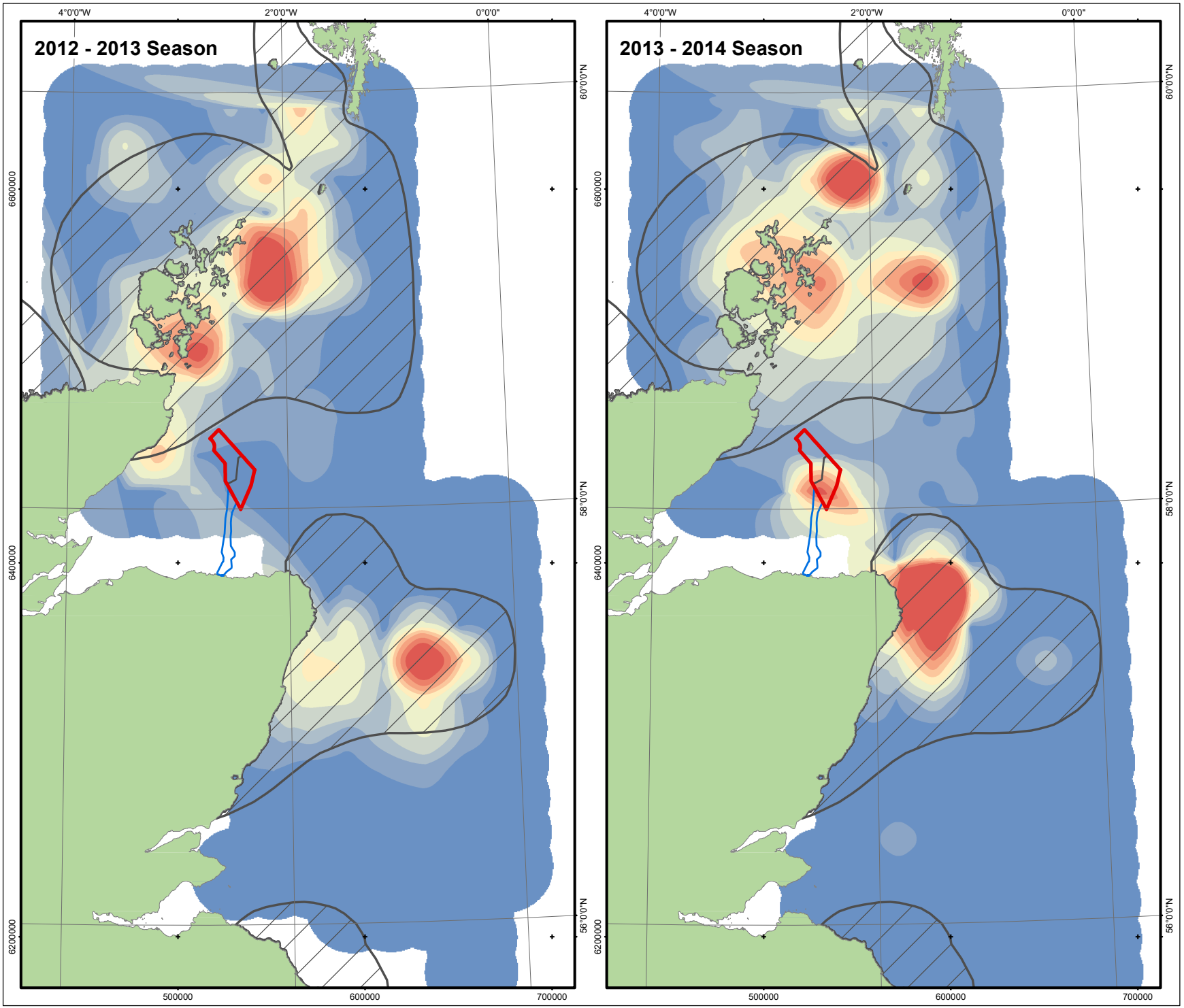

Caledonia OWF

Offshore Export Cable Corridor

Caledonia North Site and Caledonia South Site Division Line

Herring Spawning Grounds (Coull et al., 1998)

IHLS - Larval abundance per m^2

- 0 - 150
- 150.1 - 350
- 350.1 - 550
- 550.1 - 950
- 950.1 - 1,450
- 1,450.1 - 2,000
- 2,000.1 - 2,600
- 2,600.1 - 3,500
- 3,500.1 - 4,500
- 4,500.1 - 6,250

0 20 40 60 80 100 km

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Figure 3-5: Density of Herring Larvae (IHLS Years 2012 and 2013)

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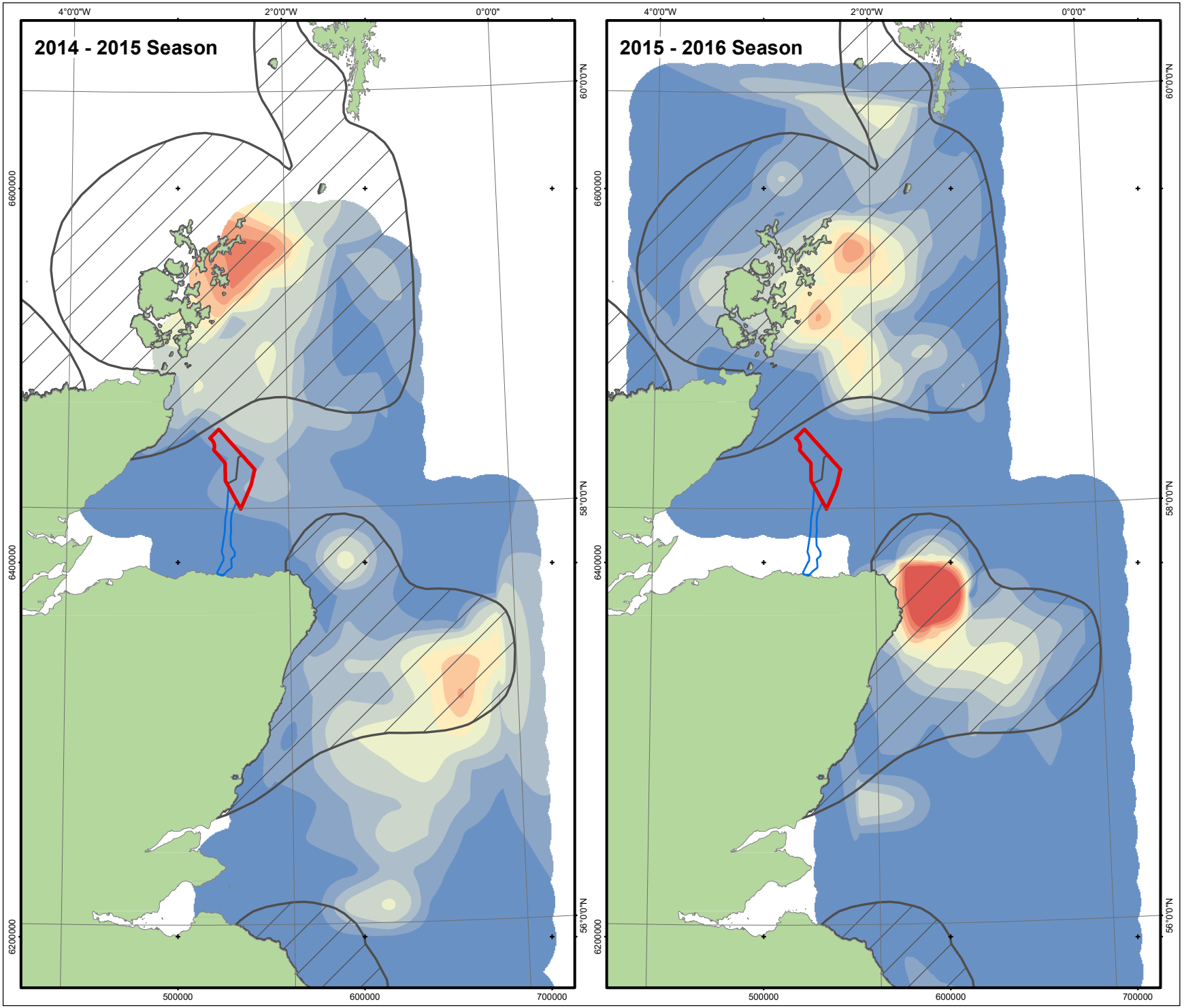

Caledonia OWF

Offshore Export Cable Corridor

Caledonia North Site and Caledonia South Site Division Line

Herring Spawning Grounds (Coull et al., 1998)

IHLS - Larval abundance per m^2

- 0 - 150
- 150.1 - 350
- 350.1 - 550
- 550.1 - 950
- 950.1 - 1,450
- 1,450.1 - 2,000
- 2,000.1 - 2,600
- 2,600.1 - 3,500
- 3,500.1 - 4,500
- 4,500.1 - 6,250

0 20 40 60 80 100 km

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Figure 3-6: Density of Herring Larvae (IHLS Years 2014 and 2015)

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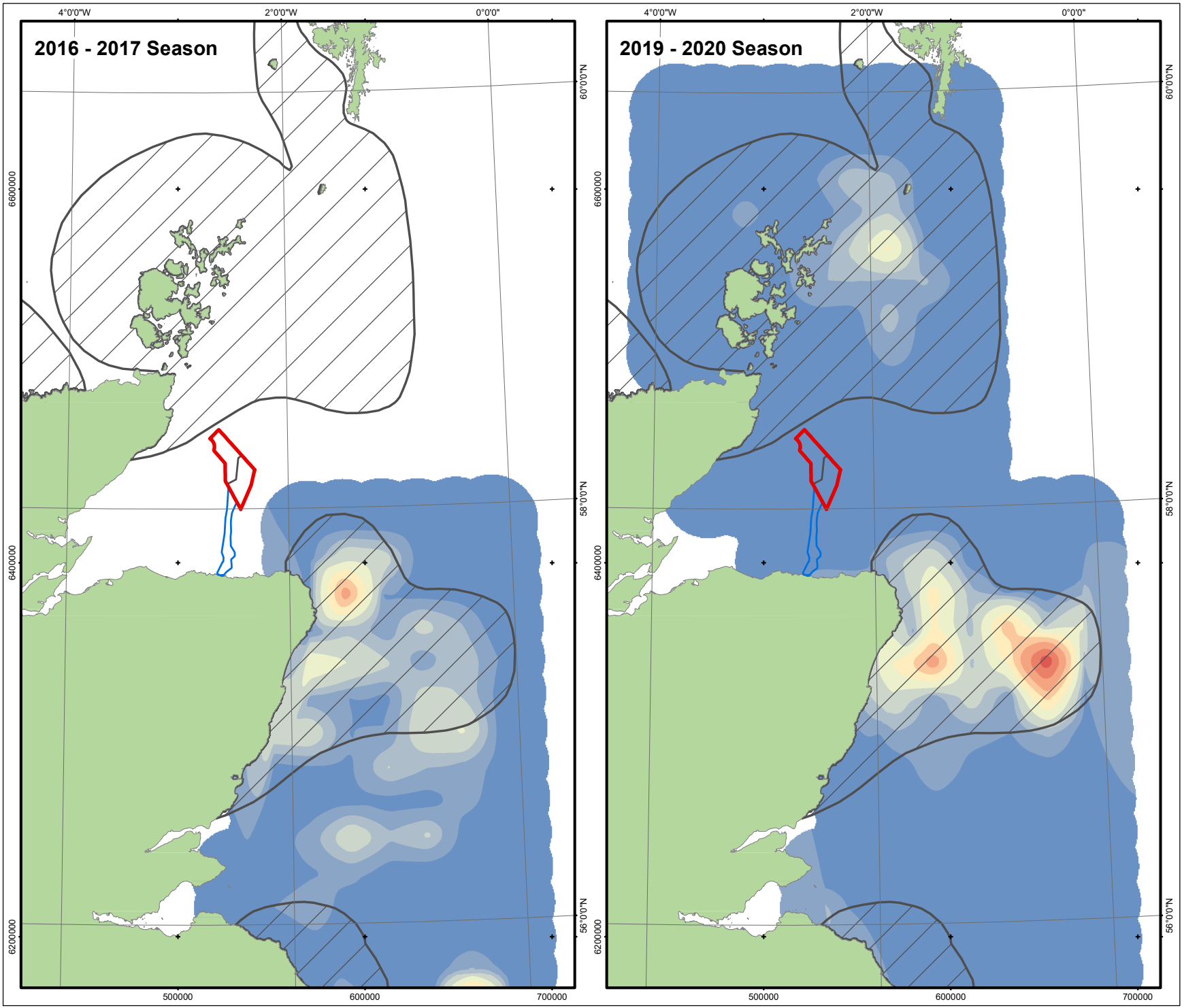

Caledonia OWF

Offshore Export Cable Corridor

Caledonia North Site and Caledonia South Site Division Line

Herring Spawning Grounds (Coull et al., 1998)

IHLS - Larval abundance per m^2

- 0 - 150
- 150.1 - 350
- 350.1 - 550
- 550.1 - 950
- 950.1 - 1,450
- 1,450.1 - 2,000
- 2,000.1 - 2,600
- 2,600.1 - 3,500
- 3,500.1 - 4,500
- 4,500.1 - 6,250

0 20 40 60 80 100 km

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Figure 3-7: Density of Herring Larvae (IHLS Years 2016 and 2019)

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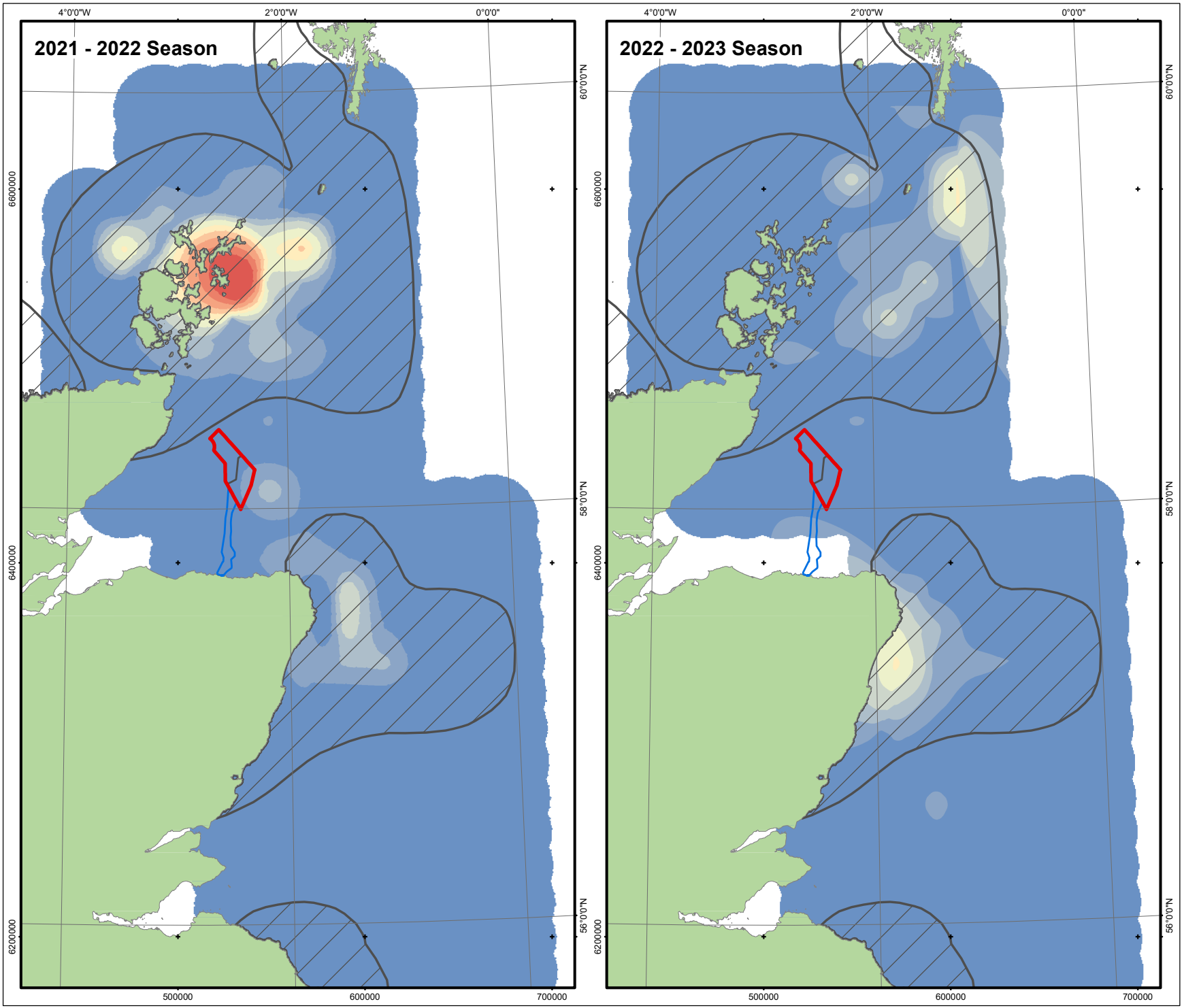

Caledonia OWF

Offshore Export Cable Corridor

Caledonia North Site and Caledonia South Site Division Line

Herring Spawning Grounds (Coull et al., 1998)

IHLS - Larval abundance per m^2

- 0 - 150
- 150.1 - 350
- 350.1 - 550
- 550.1 - 950
- 950.1 - 1,450
- 1,450.1 - 2,000
- 2,000.1 - 2,600
- 2,600.1 - 3,500
- 3,500.1 - 4,500
- 4,500.1 - 6,250

0 20 40 60 80 100 km

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GEODETIC PARAMETERS
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DRAWING TITLE

Figure 3-8: Density of Herring Larvae (IHLS Years 2021 and 2022)

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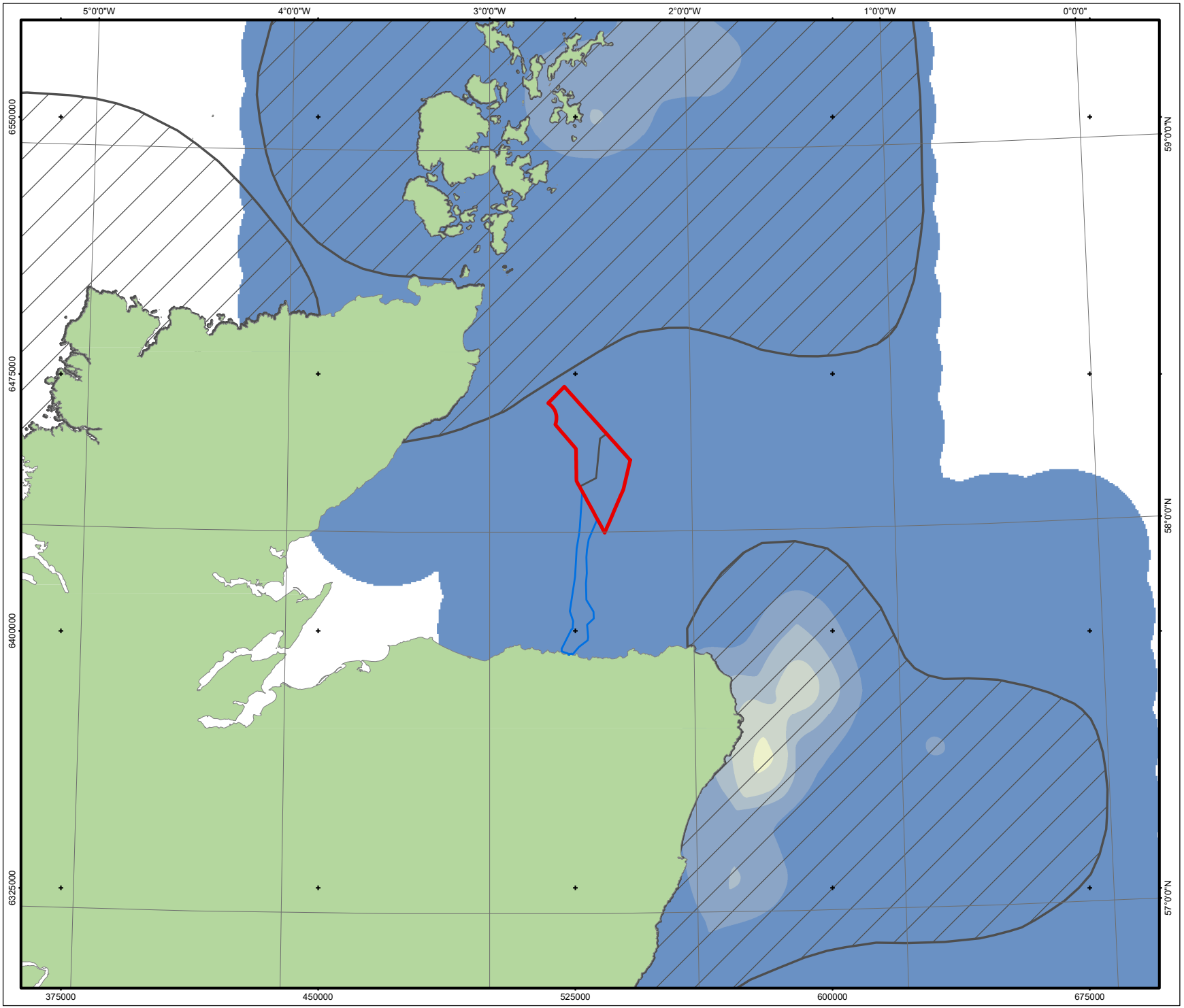
DRAWING NUMBER	SHEET NO	REV
N/A	01 of 01	N/A



Caledonia OWF

Offshore Export Cable Corridor

Caledonia North Site and Caledonia South Site Division Line

Herring Spawning Grounds (Coull et al., 1998)

IHLS Season 2023-2024 - Larval abundance per m^2

- 0 - 150
- 150.1 - 350
- 350.1 - 550
- 550.1 - 950
- 950.1 - 1,450
- 1,450.1 - 2,000
- 2,000.1 - 2,600
- 2,600.1 - 3,500
- 3,500.1 - 4,500
- 4,500.1 - 6,250

0 10 20 30 40 50 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	16/09/2025	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm

GoBe APEM Group

GEODETIC PARAMETERS
WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE

Figure 3-9: Density of Herring Larvae (IHLS Year 2023)

STATUS	SCALE	
Approved	1:1,500,000	
DRAWING NUMBER: N/A	SHEET NO: 01 of 01	REV: N/A

3.3.3 Temporal Threshold Shift

3.3.3.1 As discussed in paragraph 5.7.1.145 *et seq.* in Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology, the noise contours from piling at the Caledonia OWF shown in relation to historic Buchan and Orkney/Shetland herring spawning grounds (Coull *et al.*, 1998) and recent IHLS larvae densities (IHLS data 2011-12 to 2023-24) indicate the potential for piling to induce TTS in spawning herring from the Buchan and Orkney/Shetland spawning stocks (Figure 3-3 and Figure 3-4). However, as indicated by the annual IHLS data (Figure 3-5 to Figure 3-9), the area over which TTS may occur would be restricted to areas that typically show low to medium herring spawning activity. Additionally, the IHLS data suggest a wide distribution of spawning activity outside the areas predicted to be affected by TTS (Figure 3-3 and Figure 3-4).

3.3.3.2 Concerning potential impact ranges, it should be noted that, as outlined in paragraph 5.7.1.5 of Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology, the maximum hammer energies assumed in the worst-case scenario are likely to be precautionary and that in fact for many piling events, a lesser hammer energy will be required to complete the pile installation. This is because the maximum energy needed at each foundation location will depend on the specific ground conditions, with the maximum hammer energy considered in the modelling being based on the location that would require the largest hammer energies during piling. As such, the assumed maximum hammer energies represent the upper limit of the equipment, rather than the likely energy that will be required to install any given foundation. Consequently, the spatial extent over which piling noise may affect spawning herring is likely to be smaller for many piling events compared to the maximum impact ranges predicted by the modelling.

3.3.3.3 Additionally, as described in paragraph 5.7.1.145 *et seq.* of Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology, the TTS impact ranges have been modelled on the assumption that impulsive noise characteristics remain the same over distance. Recent studies on the range dependent nature of impulsive sounds produced by seismic airguns, pile driving and underwater explosions showed a marked change in the impulsiveness of sounds with distance from the sound source, with impulsive sound characteristics becoming more similar to non-impulsive (continuous) sounds as the sound wave propagates through the marine environment (Hastie *et al.*, 2019[14]; ORJIP, 2024[15]). The greatest change in several of the acoustic properties of impulsive sounds occurred within 5-10km from the sound source, suggesting that predicted impact ranges for TTS in fish, which for stationary receptors typically extend far beyond 10km, may not necessarily be representative of the true risk of TTS at far distances from the piling location. Current underwater noise models cannot account for changes in the impulsive nature of sound, and consequently there is

potential that the risk of TTS has been overestimated at the large ranges predicted from the modelling.

3.3.3.4 Based on the above considerations and given the intermittent and short-term nature of piling and the temporary nature of TTS in fishes, it has been concluded that any TTS in spawning herring during the piling of foundations at the Caledonia OWF would comprise a discernible but temporary change over a minority of both the Buchan and Orkney/Shetland spawning components. Therefore, the Applicant maintains that the conclusion of a **Low** (adverse) magnitude of impact with respect to TTS remains valid.

3.3.4 Auditory Masking and Behavioural Effects

3.3.4.1 The Applicant also considers that the conclusion of **Low** magnitude is appropriate for potential auditory masking and behavioural effects in Atlantic herring. As detailed in paragraphs 5.7.1.168 *et seq.* of Volume 2, Chapter 5: Fish and Shellfish Ecology, there are currently no quantitative thresholds advised to be used to assess auditory masking and behavioural effects in fishes during piling activities. Therefore, a qualitative assessment has been undertaken based on the qualitative criteria recommended by Popper *et al.* (2014[6]). These criteria categorise the risks of auditory masking and behavioural disturbance in relative terms as 'high', 'moderate' or 'low' at three distances from the noise source: near (10s of metres), intermediate (100s of metres), and far (1000s of metres), respectively. As detailed in paragraphs 5.7.1.191 *et seq.* of Volume 2, Chapter 5: Fish and Shellfish Ecology, the risk of behavioural and auditory masking effects in Atlantic herring from pilling is expected to be high in the near and intermediate fields and moderate in the far fields.

3.3.4.2 It is acknowledged in the impact assessment presented in Volumes 2, 3 and 5, Chapter 5: Fish and Shellfish Ecology that there is potential for behavioural effects in spawning herring due to the proximity of the Buchan and Orkney/Shetland herring spawning grounds. However, the IHLS data indicate that the area over which auditory masking and behavioural effects are most likely to occur (i.e., within 10s to 100s of metres from the piling location) typically show low to medium herring spawning activity. As discussed previously, the IHLS data further show a wide distribution of spawning activity within the fish and shellfish ecology study area and wider northern North Sea region.

3.3.4.3 Like TTS, any auditory masking and behavioural changes in herring would be temporary, and affected individuals are anticipated to resume normal behaviour and distribution after piling has ceased. In addition, as discussed in paragraph 3.2.1.3 of this appendix, there is evidence that behavioural responses in herring to vessel noise and seismic airguns are reduced when they are involved in key biological behaviours such as feeding and

spawning. A similar override of any potential deterrence effects may occur in spawning herring when exposed to pile driving.

3.3.4.4 Based on the above considerations and given the intermittent and short-term nature of piling, it has been concluded that any potential auditory masking and behavioural disturbance in spawning herring during piling would comprise a temporary change over a minority of both the Buchan and Orkney/Shetland spawning components. Consequently, the magnitude of impact in relation to auditory masking and behavioural effects has been deemed to be **Low**.

3.4 Magnitude of Potential Cumulative Impacts

3.4.1.1 As detailed in Section 5.8.2 of Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology, there are several projects in the vicinity of Caledonia OWF that may give rise to cumulative effects in fish and shellfish species. The greatest risk of cumulative effects of underwater noise on herring has been identified as being that produced by impact piling during the construction phase of other offshore wind development sites, specifically piling at Salamander, Pentland Floating, Broadshore, Buchan, Ayre and Stromar OWFs due to potential overlaps in piling programmes.

3.4.1.2 As described in paragraph 5.8.2.11 *et seq.* of Volume 2, Chapter 5: Fish and Shellfish Ecology, it is anticipated that the maximum UWN impact ranges arising from these projects alone would be similar to those predicted for Caledonia OWF, given similar scales of development and technologies of the considered OWFs. Given the distance between the projects (the nearest project to Caledonia OWF is the Stromar OWF located approximately 22km northeast from Caledonia OWF), the maximum impact ranges for the onset of mortality, potential mortal injury and recoverable injuries in stationary herring are unlikely to overlap between projects. It is acknowledged that piling at the identified OWFs has the potential to result in additive mortality and recoverable injury in herring and their eggs and larvae. However, the IHLS data suggest that these projects are located in areas of no, low or medium herring spawning activity outside the areas of peak herring spawning of the Buchan and Orkney/Shetland spawning stocks. It is therefore the Applicant's view that the magnitude of potential cumulative mortality and recoverable injury in herring as a result of concurrent or sequential piling at the identified OWF projects remains **Low** and will not lead to material changes to the Buchan and Orkney/Shetland spawning stocks. On this basis, the Applicant considers the magnitude assessment of **Low** (adverse) for cumulative mortal and recoverable injuries, as presented in Chapter 5: Fish and Shellfish Ecology of Volumes 2, 3 and 4, to be appropriate

3.4.1.3 The potential for cumulative TTS and behavioural effects in fish, including herring, has been discussed in paragraph 5.8.2.17, 5.8.2.15 and 5.8.2.15 (respectively) of Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology. Modelling of simultaneous piling at Caledonia OWF and Broadshore OWF predicted a small increase in the overall impact ranges for TTS compared to the modelled TTS impact range for the Proposed Development (Offshore) alone, as shown in Figure 5-24 of Volume 2, Chapter 5: Fish and Shellfish Ecology. It is further acknowledged that cumulative TTS or behavioural reactions arising from piling at the identified projects may be sufficient to result in temporary avoidance of areas affected by UWN, with some temporary redistribution of fish in the wider area between the affected areas. However, it is anticipated that the duration of piling at each OWF construction site will be short-term and that any TTS and behavioural effects would be intermittent, and reversible. Therefore, the Applicant maintains that the conclusion of a **Low** (adverse) magnitude of impact with respect to potential cumulative TTS and behavioural effects remains valid.

4 Mitigation and Monitoring

4.1.1.1 The assessments within the relevant sections of the EIAR (Volumes 2, 3 and 4, Chapter 5: Fish and Shellfish Ecology) have not identified any potential significant effects to Atlantic herring requiring additional mitigation. Therefore, the Applicant does not consider it necessary to commit to mitigation for Atlantic herring as a direct result of this assessment.

4.1.1.2 Notwithstanding, the Applicant is committed to the development of, and adherence to, a Piling Strategy, which will detail the method of pile installation and associated noise levels and soft-start and ramp up procedures during piling activities. Moreover, as set out in Volume 7, Appendix 8: Caledonia North Offshore Schedule of Mitigation and Volume 7, Appendix 9: Caledonia South Offshore Schedule of Mitigation of the EIAR, the Applicant is committed to the development of a Project Environmental Monitoring Plan (PEMP), which will set out commitments to environmental monitoring in pre-, during and post- construction phases of Caledonia North and Caledonia South. The PEMP will be developed post-consent once further detailed design work has been completed for Caledonia North and Caledonia South and post-consent requirements and consent conditions are agreed. The PEMP will be prepared in consultation with key stakeholders for submission to, and approval by MD-LOT prior to the commencement of construction.

4.1.1.3 Whilst the Applicant believes that no additional mitigation is required for Atlantic herring, and other fishes, strategic monitoring of herring could be considered to validate the conclusions of the EIAR and to fill some of the evidence gaps in relation to the effects of piling on spawning herring. The scope and details of such monitoring would form part of the PEMP.

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